Branched Renal Calculi

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*Surgical operation on 30 kidneys was carried out for branched renal calculi,
with no operative mortality. Of 23 kidneys in which conservative surgical proce-
dures were used, 83 percent are now stone-free. When all stones were success-
fully removed, cultures of urine were sterile in 80 percent of cases, but when
fragments remained, no patient was infection-free. It was found that impaired
renal function need not be a contraindication to surgical operation, and indeed
that in five of seven patients with impaired renal function, serum creatinine
levels either remained stable or improved. We believe that surgical removal is
the most conservative management of branched renal calculi.*

ALTHOUGH RENAL-CONSERVING surgical operation
for branched renal calculi has been done for at
least a hundred years, the very nature of these
stones makes such operation potentially hazard-
ous. Before ten years ago, because of the gen-
erally poor results and high complication rate,
such surgical procedures never achieved wide-
spread popularity despite scattered reports show-
ing that operative intervention, including neph-
rectomy, was superior to medical management
alone.[1,2] Blandy examined his experience with
the unoperated staghorn calculus and concluded
that expectant treatment led to nephrectomy, often
for the dreaded complication of pyonephrosis, in
half of the patients not operated on, and death
from progressive renal failure in most of the re-
mainder.[3,4] Technical advances in just the past
decade[5-7] have made nonablative surgical opera-
tion for staghorn calculi common, if not routine,
and the results fully support the contention that
surgical intervention rather than expectant medi-
cal management is the more conservative treat-
ment plan.[8,9]

We have examined our surgical experience with
staghorn calculus to evaluate: (1) our success
rate using a variety of surgical approaches, (2)
the interrelationship of residual stone fragments,

infection and stone recurrence and (3) the in-
fluence of impaired renal function on surgical suit-
ability.

Clinical Data

Since July 1970 we have evaluated the cases
of 33 consecutive patients with 38 staghorn cal-
culi, all but five of whom received surgical treat-
ment. Of the five unoperated patients, two
declined surgical treatment and three were con-
sidered medically unfit because of advanced age
or severe heart disease with angina, in the pres-
ence of stable renal function. Of the remaining
28 surgical patients, there were 19 women and
9 men. Their ages ranged from 11 through 75
years. The presenting complaint was pain in 15
patients; in all but two urinary tract infection
was present. In all, metabolic studies and pre-
operative and postoperative evaluation of renal
function were made. Two patients had been
previously treated for hyperparathyroidism, and
one was known to have cystinuria.

Thirty surgical procedures were carried out in
28 patients (bilateral operations were done in
two) (Table 1). Nephrolithotomy was done in
ten patients using the technique described in 1967
by Smith and Boyce.[5] The term "anatrophic
nephrotomy" was used by Smith and Boyce to
suggest the all-inclusive concept of preoperative
surgical measures and postoperative actions de-
signed to minimize atrophy of the renal paren-

chyma. Selective renal hypothermia was used in all nephrolithotomies,[7] and intraoperative radiographic control was considered indispensable. In four patients, a nephrostomy tube was placed intraoperatively to permit Renacidin® irrigation. In nine patients, extended pyelolithotomy was carried out using the technique of Gil-Vernet,[6] with isolated nephrotomy in five and partial nephrectomy in two. In two other patients, stones were removed with partial lower pole nephrectomy alone. Seven primary nephrectomies were done, five because of nonfunction as shown by excretory urography and renal scan. Two followed attempted nephrolithotomies that were deemed unsuccessful intraoperatively because of the extent of parenchymal disease. In two patients, ex vivo or "bench" surgical procedures were done—that is, the procedures were carried out after nephrectomy while the kidney was sustained by extracorporeal pulsatile perfusion with cryoprecipitated plasma using the Travenol Viacell® perfusion apparatus (Travenol Laboratories, Morton Grove, Illinois). Both procedures were extended pyelolithotomies, one with multiple nephrotomies, and the other with a partial nephrectomy. Following successful removal of all stones, these kidneys were autotransplanted to the contralateral iliac fossa. Bench surgical operation was selected in the first case because of the dual presence of a staghorn calculus and a surgically correctable arterial lesion, and in the second because of the absence of most of the ureter as a result of surgical procedures done previously.

TABLE 1.—Operative Procedures

Anatrophic nephrolithotomy with local hypothermia	10
Extended pyelolithotomy with or without nephrotomy	7
Extended pyelolithotomy with partial nephrectomy	2
Partial nephrectomy alone	2
Bench surgery with extracorporeal perfusion (both extended pyelolithotomies)	2
Primary nephrectomy	7
	30

TABLE 2.—Current Status (Average Follow-up, 25 Months)

Stone free	19	(83%)
Conservative operations (23 kidneys)		
Immediately stone free	16	
Fragment passed	4	
(recurrence 1)		
Stone present	4	(17%)
Residual fragments	3	
Unchanged	2	
Enlarged	1	
Recurrence	1	

In all patients in whom conservative surgical procedures were done, specific antibiotic therapy was continued for at least six months postoperatively.

Results

Surgical

Patient follow-up now ranges from 3 to 63 months, for an average of 25 months. In all, 23 conservative procedures have been done in 21 patients, with 16 of the kidneys being rendered stone-free at the time of operation. In seven kidneys there were small retained stone fragments. In four of these, however, all fragments have subsequently passed spontaneously (Table 2). In two of the remaining three kidneys, residual fragments have shown no change in size, while one was enlarged slightly.

Four kidneys with retained fragments were treated by postoperative Renacidin irrigation.[10] One patient received an insignificant amount because of the onset of pain and a rash. Three kidneys were irrigated for a total of three, four, and six weeks respectively. Several fragments became slightly smaller, but only one disappeared completely, and that in a kidney with several fragments remaining. In this latter patient, all fragments subsequently passed and the patient also is free of infection.

In none of the patients in our series has a new stone formed in the contralateral unoperated kidney, and in only one patient has there been recurrence of a stone. Therefore, excluding the patients in whom nephrectomy was done, 19 of 23 kidneys in our series are free of stones at present—a cure rate of 83 percent.

Renal Function

In 20 of our 28 patients, preoperative levels of serum creatinine were normal and remained stable following operation. In eight patients, there was depressed preoperative renal function with either serum creatinine over 1.5 mg per 100 ml or creatinine clearance less than 60 ml per minute. Of these eight, conservative procedures were carried out in seven. In none of the patients was surgical operation not done because of impaired renal function. Postoperatively in five of these patients renal function either improved or showed no change, while in only two patients did renal function decline (Table 3). In one of these two patients, delayed nephrectomy was done for

TABLE 3.—*Impaired Preoperative Renal Function*

Patient	Pre-operative Cr/Ccr	Post-operative Cr/Ccr	Procedure
1 ...	1.8/58	1.1/75	Anatrophic nephrolithotomy with contralateral nephrectomy
2 ...	2.2/37	1.3/..	Right pyelolithotomy; Left extended pyelolithotomy
3 ...	1.9/30	1.6/..	Extended pyelolithotomy
4 ...	1.9/46	1.9/50	Extended pyelolithotomy
5 ...	4.5/10	2.7/16	Extended pyelolithotomy
6 ...	1.2/58	1.9/32	Bench; secondary nephrectomy
7 ...	3.8/11	7.9/08	Anatrophic nephrolithotomy

Cr/Ccr = serum creatinine level/creatinine clearance

hemorrhage, although in this patient postoperative function before nephrectomy was improved over preoperative values. In the second patient there was a serum creatinine value of 3.8 mg per 100 ml and clearance of 11 ml per minute before surgical operation. Renal function at first was stable following nephrolithotomy (clearance 15 ml per minute one week after operation); however there was a slow but complete deteriora-

tion in renal function during the next 22 months.

One patient presented with a solitary kidney and a serum creatinine value of 10.3 mg per 100 ml with clearance of 2.5 ml per minutes. With correction of dehydration, we were able to improve the serum creatinine level and clearance to 4.5 mg per 100 ml and 10 ml per minute, respectively. Postoperatively, following successful removal of all stone fragments, these values improved further, to 2.7 mg per 100 ml and 16 ml per minute.

Infection

The close relationship between infection and the presence of stones has been supported by our data. Preoperatively, in 93 percent of patients infections were present despite previous appropriate antibiotic therapy. In 15, the infecting organism was Proteus, either alone or with Escherichia coli. E. coli alone accounted for another six. Postoperatively, in 12 patients infections are still present. To make a proper correlation between infection and presence of stones, however, we must
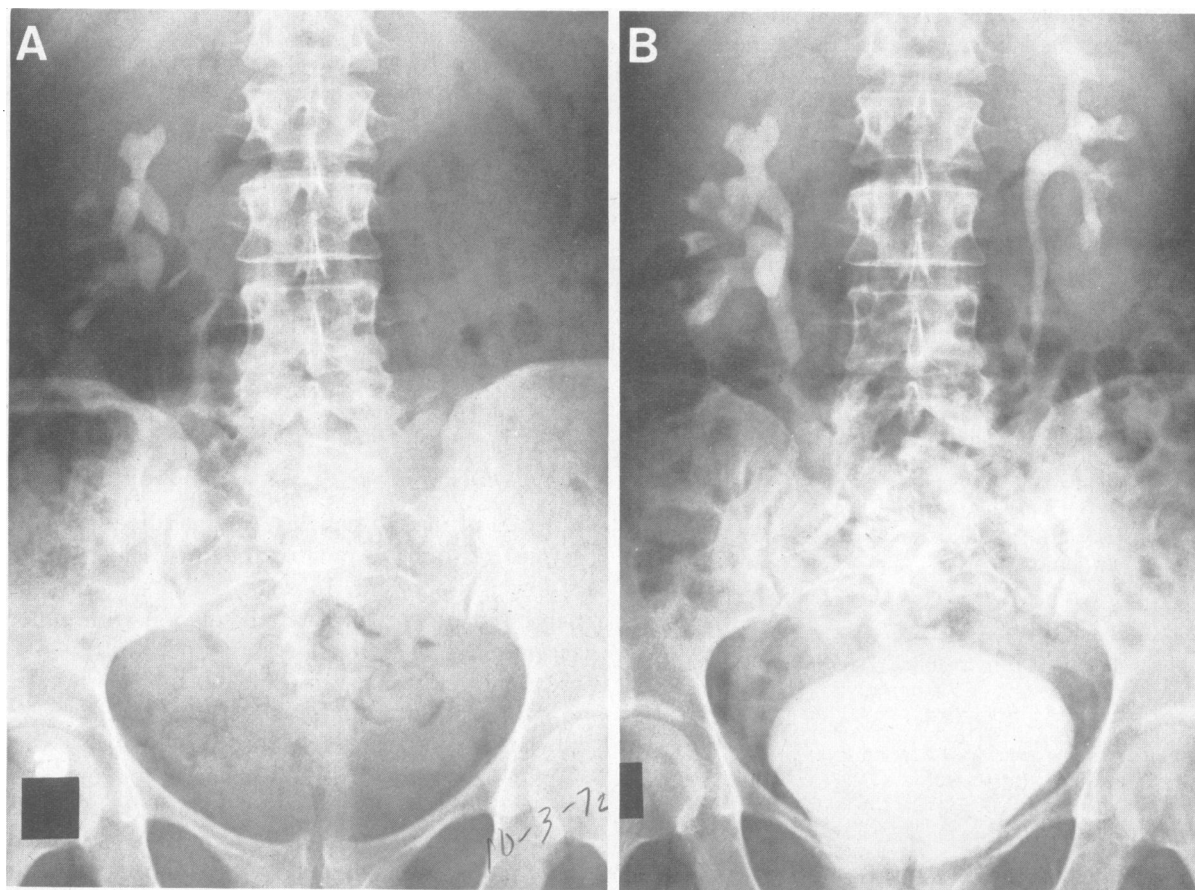

Figure 1.—(Case 1) **A,** Preoperative plain abdominal film showing moderate-sized branched renal calculus in right kidney, **B** Preoperative excretory urogram showing moderate obstruction from stone.

exclude four patients. In two patients in whom there are infections but no stones, indwelling Foley catheters have been placed for the neurogenic bladders, and in a third patient infected stones are present in the contralateral, as yet unoperated kidney. In a fourth patient, in whom a delayed nephrectomy was done for nonfunction, there are no stones but severe chronic pyelonephritis and an ileal loop diversion are present. Excluding these four, our overall postoperative infection rate is 33 percent. More important, however, when retained stones are present the infection rate is 100 percent; but when all stones have been removed the infection rate falls to only 20 percent.

Eighteen stones were crushed and cultured. Three stones were sterile and for the remaining 15 there were positive findings on cultures. Of 20 stones sent for crystallographic analysis, in 18 there were various proportions of magnesium ammonium phosphate (struvite) and apatite, the former usually predominant, and occasionally small amounts of calcium oxalate intermixed. Two stones (one patient with bilateral staghorns) were pure cystine.

Complications

There were three major complications in our series. A delayed nephrectomy was necessary for hemorrhage in a patient nine days after renal bench surgical operation with autotransplantation. In a second patient, nephrectomy was carried out for nonfunction and chronic infection 22 months after the original nephrolithotomy (Patient 6, Table 3). In a third patient there was a nonfatal pulmonary embolus after discharge from hospital. In all 30 operations, the average number of blood transfusions during and immediately following operation was two units. Average postoperative time in hospital was 15.3 days, but excluding those patients kept in hospital for prolonged periods for Renacidin irrigation reduces this figure to just under 11 days.

Reports of Cases

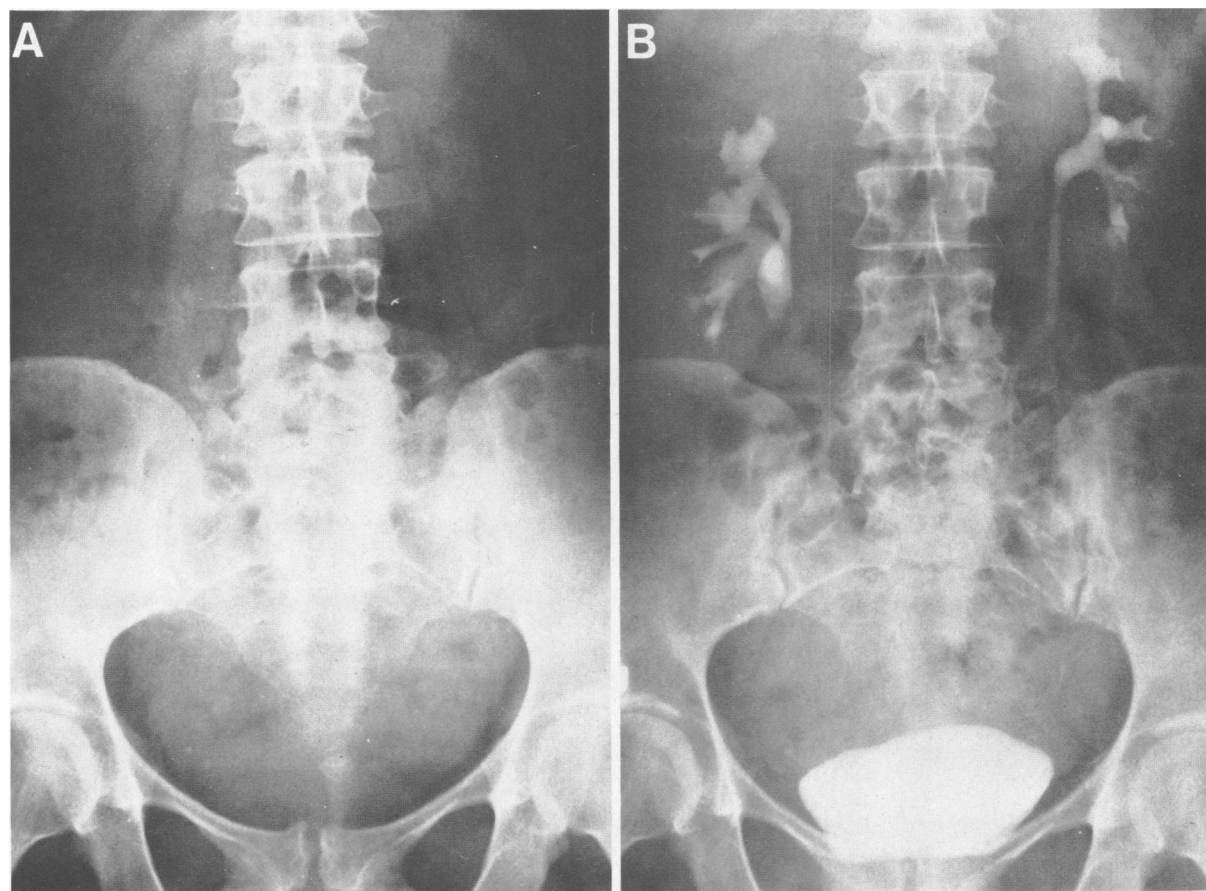Several case histories will serve as representative examples.

Figure 2.—(Case 1) A, Postoperative plain film showing complete removal of staghorn calculus. B, Excretory urogram three months after nephrolithotomy showing mild residual dilatation of right collecting system.

BRANCHED RENAL CALCULI

Case 1.—In a 37-year-old white woman the first urinary tract infection occurred at age 30. Findings on an excretory urogram after a second infection two years later showed a large staghorn calculus with partial obstruction but good function (Figure 1). Because of flank pain, persistent Proteus mirabilis infection, and steady growth in size of stone, she was referred to the University of California, Davis—Sacramento Medical Center (UCD-SMC) for therapy in late 1972.

Findings on physical examination were unremarkable. The serum creatinine value was 0.8 mg per 100 ml with a clearance of 78 ml per minute. Calcium and phosphorus values were normal. Urine culture grew more than 100,000 colonies per ml of Proteus mirabilis. An arteriogram showed a single renal artery and good parenchyma.

On October 6, 1972 a retrograde pyelogram was carried out followed by an anatrophic nephrolithotomy under selective hypothermia. Ischemia time was 75 minutes, and there were

no residual calculi shown to be present intraoperatively by kidney-sized x-ray cassettes.

Results of stone analysis showed struvite 60 percent and apatite 40 percent, and culture of the crushed stone grew Proteus mirabilis. Postoperative urine cultures were sterile until six months later, when again they grew more than 100,000 colonies per ml of Proteus mirabilis. On x-ray film, a 6 X 22 mm spindle-shaped stone was seen in the distal ureter; subsequently it passed spontaneously. Culture of this crushed stone also grew Proteus mirabilis. A follow-up excretory urogram ten months after the original surgical operation showed no stone fragments and good function (Figure 2), and urine culture was sterile.

Case 2.—A 43-year-old black woman had onset of malaise, dysuria and frequency, and right flank pain in early 1970. After two years of treatment with antibiotics without appreciable relief, a period during which the patient lost 20 pounds, she was referred to UCD-SMC for definitive treatment.
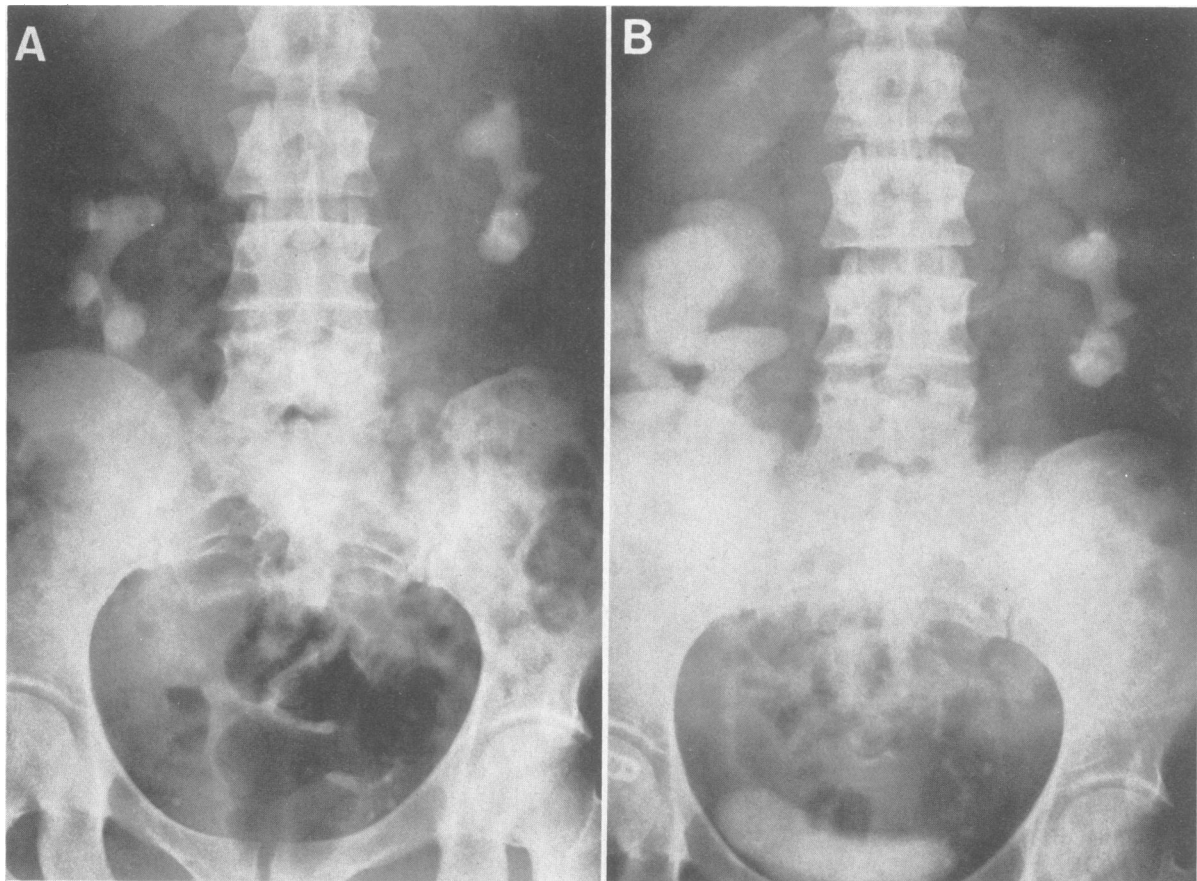

Figure 3.—(Case 2) A, Preoperative plain abdominal film showing bilateral staghorn calculi. B, Preoperative excretory urogram at one hour showing severe obstruction on right and nonfunction on left.

On physical examination at the time of admission the patient was seen to be thin and appeared chronically ill. A tender, ballottable mass in the right upper quadrant was noted. Hemoglobin level was 8.3 grams per 100 ml, calcium and phosphorus values were normal and the serum creatinine level and creatinine clearance were 2.1 mg per 100 ml and 60 ml per minute, respectively. Urine culture grew more than 100,000 colonies per ml of E. coli.

Findings on an excretory urogram included bilateral staghorn calculi, notably delayed function and hydronephrosis of the right kidney (Figure 3), and nonfunction of the left (confirmed by renal scan). An arteriogram showed pronounced cortical atrophy of the entire left kidney and the right lower pole.

On September 13, 1972 retrograde pyelography followed by an anatrophic right nephrolithotomy was carried out under selective hypothermia. Stone analysis showed 70 percent struvite, 28 percent apatite and 2 percent brushite; culture grew E. coli

and Proteus mirabilis. On pathologic examination of the lower pole there was severe acute and chronic pyelonephritis with xanthogranulomatous reaction. One month later, exploration of the left kidney failed to show any potentially salvageable kidney, and a left nephrectomy was carried out. Postoperatively, the creatinine level fell to 1.5 mg per 100 ml and creatinine clearance improved to 75 ml per minute. Urine culture was sterile and on excretory urogram three months postoperatively no stone fragments were noted and there was improvement shown in right-sided hydronephrosis (Figure 4).

Discussion

At present the most popular surgical approaches for branched renal calculi are anatrophic nephrolithotomy, extended pyelolithotomy and partial nephrectomy. Each approach has its own proponents, but it has been our experience that no single operative procedure is adaptable to all clinical situations. Thoroughness of stone
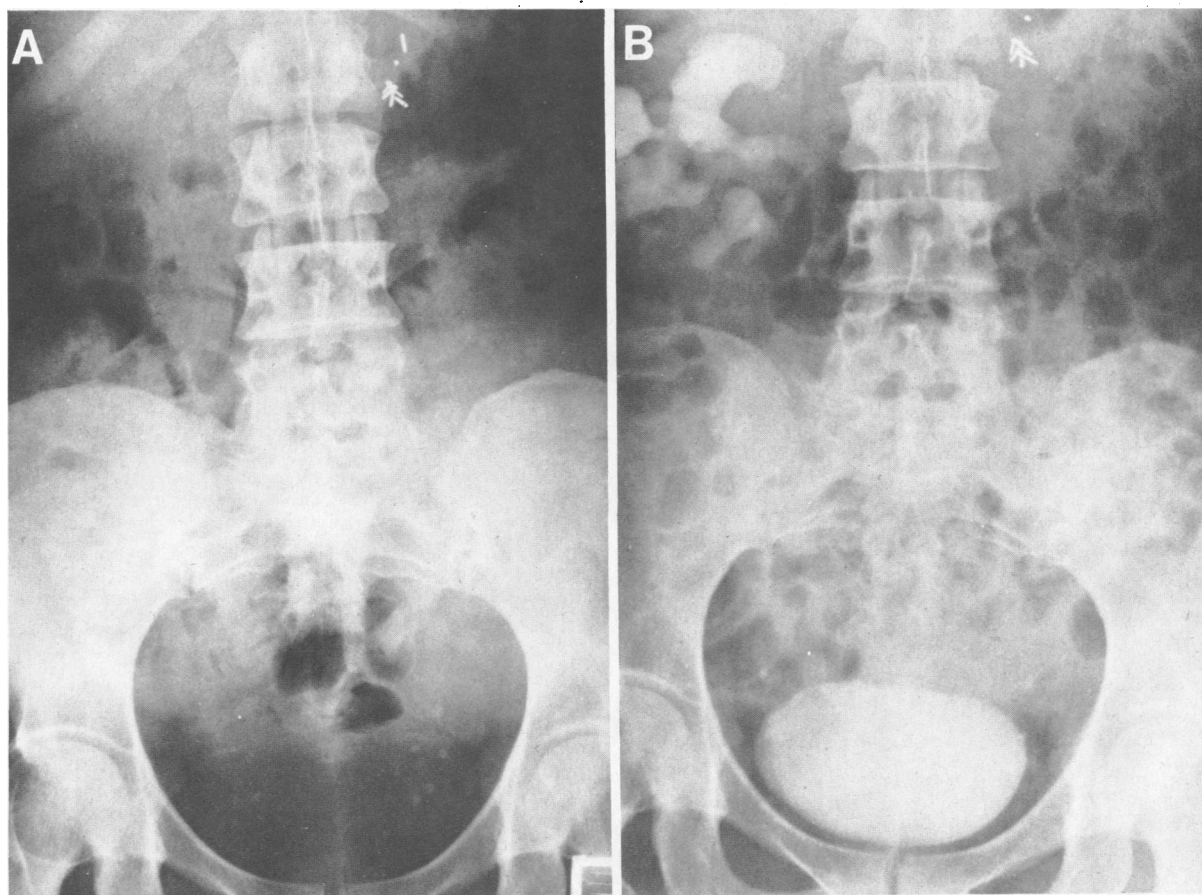

Figure 4.—(Case 2) **A,** Postoperative plain film showing no stones present. **B,** Excretory urogram two months after left nephrectomy and right nephrolithotomy with lower pole nephrectomy showing improvement in both obstruction and function.

removal (and thereby eradication of infection) and degree of preservation of functioning renal tissue assume major consideration in the selection of surgical approach.[5,6,10,11]

In our series of 23 conservative procedures, seven kidneys had fragments left at the time of operation, most of them very small. Four of these fragments remained following our first seven conservative procedures, and only three following our next 16. In four patients, it was not possible to locate fragments documented by intraoperative radiographs, but in three patients radiographs failed to show fragments subsequently found on postoperative films. Among the patients with retained fragments, in four the stones spontaneously passed postoperatively. Since this is not a rare occurrence in the literature,[8,11] it would seem important, if all stones cannot be completely removed, to assure that those retained be as small and as few as possible. Therefore it follows that any adjunct that might decrease the number or size of retained fragments, such as Renacidin irrigation, should be helpful. Others[15] have also supported the use of Renacidin irrigation in this manner, but it is important to remember that Renacidin irrigation of the upper tract is potentially hazardous and its use needs to be closely monitored.

Our series includes seven patients with impaired renal function preoperatively in whom conservative operations for stone removal were carried out. Although in two of these patients the kidney ultimately was lost, five of the original seven either improved or showed no change, and now have only mild functional impairment. Furthermore, although these patients did require slightly longer stays in hospital and higher blood replacement, all patients are alive today and in none of them has long-term hemodialysis been necessary. We believe that infected branched renal calculi may contribute substantially to azotemia and therefore should be removed unless such a procedure is contraindicated by other medical factors.

For many years the rate of recurrence following surgical removal of staghorn calculi was extremely high, this high rate being more the rule than the exception.[2] More recently, however, with improvement in surgical techniques and control of infection, recurrence rates have decreased considerably and vary from 5 to 33 percent in various series.[6,8,9,11] In our series, with careful bacteriologic follow-up, in only one patient has a renal calculus re-formed.

Because of the existence of bacteria deep within the stone, the inability of antimicrobials to penetrate to depths sufficient to kill those bacteria necessitates complete removal of the stone to eradicate infection.[10] Our series showed a postoperative infection rate of 100 percent when residual stone fragments were present, but only 20 percent when all stones were removed. The likelihood of stones re-forming in patients with residual infection is quite high because of the generally higher urinary pH in the presence of urea-splitting microorganisms and the decreased solubility of both struvite and calcium salts in an alkaline medium. Both Lavengood and Marshall[12] and Sutherland[13] have reported a lower stone recurrence rate in postoperative patients in whom urine cultures are sterile, compared with those patients in whom infection remains.

While renal bench surgical operation was highly successful in one of our patients with a branched renal calculus and renal artery disease,[14] in another it resulted in emergency nephrectomy for delayed hemorrhage. The indications for this highly-specialized type of surgical therapy must be critically applied and the risks must be clearly understood. Nevertheless, during evaluation and preoperative planning, this too must be given consideration in selecting the best possible surgical approach for patients with complex stone and associated renal disease.

REFERENCES

1. Maddern JP: Surgery of the staghorn calculus. Br J Urol 39: 237-275, 1967

2. Priestly JT, Dunn JH: Branched renal calculi. J Urol 61:194-203, 1949

3. Singh M, Chapman R, Tressider GC, et al: The fate of the unoperated staghorn calculus. Br J Urol 45:581-585, 1973

4. Blandy J: The fate of the unoperated staghorn calculus. Presented at the 70th Annual Meeting of the American Urological Association, Miami, Florida, May 1975

5. Smith MJ, Boyce WH: Anatrophic nephrotomy and plastic calyrhaphy. Trans Amer Assn Genitourin Surg 59:18-24, 1967

6. Gil-Vernet JI: New surgical concepts in removing renal calculi. Urol Int 20:255-288, 1965

7. Palmer JM, Guernsey JM, Connolly JE: An experimental study of selective renal hypothermia. Am J Surg 106:224-232, 1963

8. Singh M, Tressider GC, Blandy J: The long-term results of removal of staghorn calculi by extended pyelolithotomy without cooling or renal artery occlusion. Br J Urol 43:658-664, 1971

9. Boyce WH, Elkins IB: Reconstructive renal surgery following anatrophic nephrolithotomy: Follow-up of 100 consecutive cases. Trans Amer Assn Genitourin Surg 65:126-131, 1973

10. Nemoy NJ, Stamey TA: Surgical, bacteriological, and biochemical management of "infection-stones." JAMA 215:1470-1476, 1971

11. Papathanassiadis S, Swinney J: Results of partial nephrectomy compared with pyelolithotomy and nephrolithotomy. Br J Urol 38: 403-409, 1966

12. Lavengood RW, Marshall WF: The prevention of renal phosphatic calculi in the presence of infection by the Shorr Regimen. J Urol 108:368-371, 1972

13. Sutherland JW: Recurrence following operations for upper urinary tract stone. Br J Urol 26:22, 1954

14. Sullivan MJ, Joseph E, Taylor J: Extra-corporeal renal parenchymal surgery with continuous perfusion. JAMA 229:1780-1781, 1974

15. Jacobs SC, Gittes RF: Renacidin dissolution of residual renal calculi. J Urol 115:2-4, 1976